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SEA SYSTEMS COMMAND WASHINGTON DC D L FAIRHEAD ET AL
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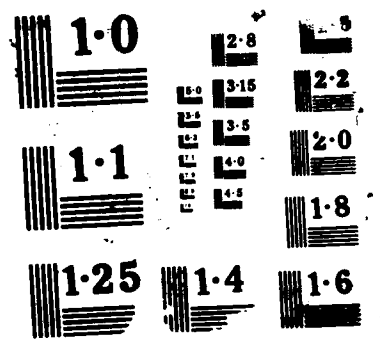
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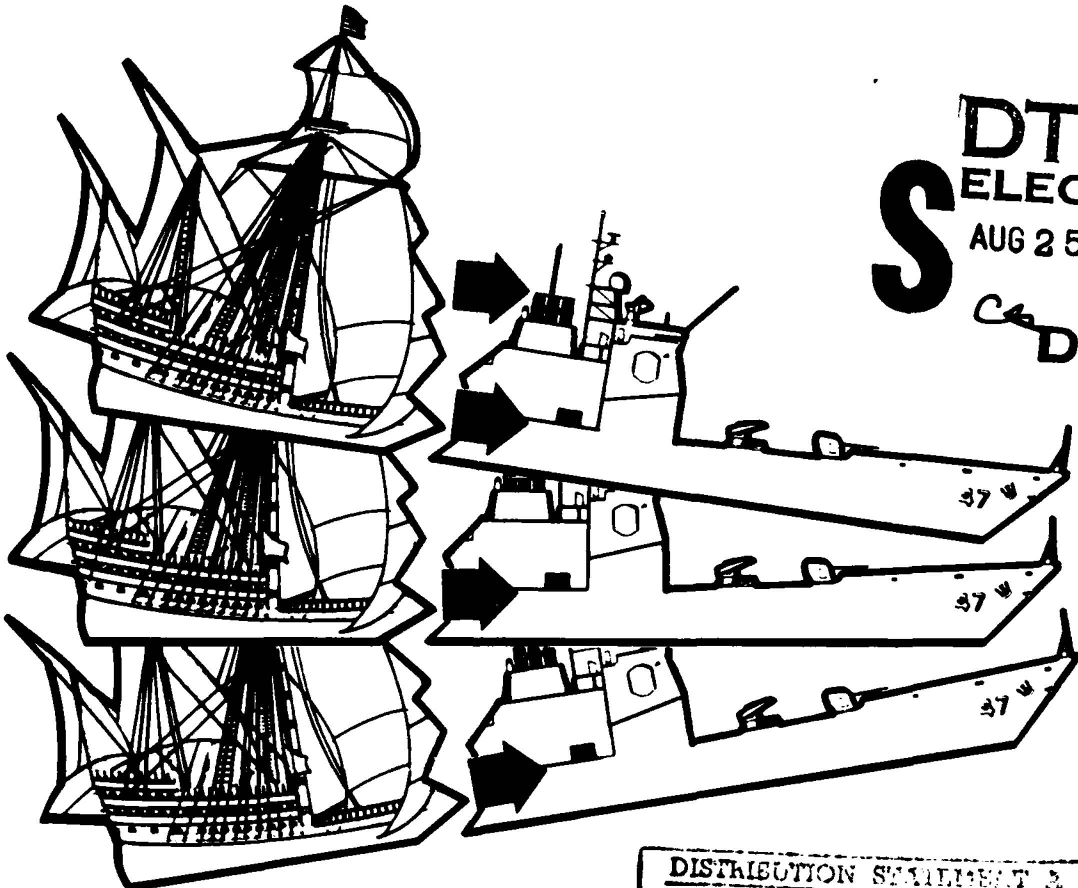

A COMPUTER MODEL FOR DAMAGE TOLERANCE ANALYSIS

by: Donald L. Fairhead, and Steven L. Cohen

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A COMPUTER MODEL FOR DAMAGE TOLERANCE ANALYSIS

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ABSTRACT

In support of the Navy's effort to improve the survivability of surface ship combat systems, a computer model is being developed by the David Taylor Naval Ship Research and Development Center to analyze tolerance for combat-induced and self-inflicted damage. A damage tolerance analysis shows the effect of damage on vital auxiliary and electrical systems and relates these damage effects to the capability of the ship to continue performing its combat mission at a prescribed level. This paper discusses ~~the~~ applications and utility of the computer model as an effective survivability analysis tool in the interactive design of ship machinery systems arrangements.

The computer model under development will allow a user to: (1) ~~to~~ define the geometry of a ship; (2) ~~to~~ define the combat systems and their associated vital auxiliary and electrical generation and distribution systems; (3) ~~to~~ simulate selective damage to the ship; and (4) ~~to~~ assess the residual combat compability. The geometry of the ship is defined in terms of compartments, firezones, and watertight areas. Combat systems and vital electrical and auxiliary generation systems, which are identified by deactivation diagrams, are defined in terms of equipment such as radars, power panels, and pumps. Distribution systems are specified by, for example, cables interconnecting the electrical power generation equipment and the critical combat systems. ~~The~~ compartment locations for all combat, vital auxiliary and electrical generation and distribution systems are specified. Damage may be specified in terms of equipments and/or areas of the ship. The model then uses this damage to determine the effects on the readiness of the ship for a specific mission, such as anti-air warfare (AAW).

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FIGURES

ABBREVIATIONS

AAW	Anti-air warfare
AFFF	Aqueous film-forming foam
ASW	Anti-submarine warfare
CAD	Computer aided design
CADSDiS	Computer Aided Design of Survivable Distributed Systems
DD-DTA	Deactivation diagram-damage tolerance analysis
DTNSRDC	David Taylor Naval Ship Research and Development Center
HM&E	Hull, mechanical and electrical
IGES	Initial graphics exchange specification
NAVSEA	Naval Sea Systems Command

INTRODUCTION

The objective of this paper is to introduce to the naval ship design community a beneficial computer tool for performing a damage tolerance analysis. A damage tolerance analysis determines whether the separation and redundancy inherent in the Hull, Mechanical, and Electrical (HM&E) systems supports the survivability requirements of the complete HM&E/Combat system. The model, called CADSDiS (Computer Aided Design of Survivable Distributed Systems), allows an interactive damage tolerance analysis to be performed during the ship design cycle. Although CADSDiS can be used in all phases of the ship design cycle, its primary uses will be in detailed design and in overhaul design. The interactive nature of the model allows the survivability analyst to quickly determine weak areas in a new or modified design, and to then try various alternatives and verify their ability to strengthen survivability in the final design.

Survivability review efforts reported elsewhere* have shown the need for survivability analyses and have helped to clarify the role of personnel involved in the design process. The cognizant engineer who "owns" a system is the only one who should design that system. When he develops the design, he must understand and satisfy a wide variety of requirements. For example, the system must meet its performance requirements, the design must address the space, weight, and cost contraints, and the "ilities" including survivability, must be evaluated, Survivability is only one of many issues that have to be considered in the design of a balanced system. The role of the survivability advocate is to help the system designer understand survivability, to provide the analytical tools, and, possibly, to do the analyses that are unique to survivability. To analyze survivability, the analyst must have the ship and system data available. Because CADSDiS is a portable software tool that works on any mainframe or minicomputer, it can be used at the activity where the data exist, by the people who have responsibility for the ship design.

CADSDiS is a deterministic assessment model (not a Monte Carlo simulation) for quantitatively estimating the damage and residual mission capability that results from assumed specific levels of battle-induced or self-inflicted damage. For these estimates to be made, the ship's geometry must be described, and the functional relationships between HM&E and combat systems must be developed. Then the combat, HM&E equipment, and distributive runs must have their compartment locations defined, and the effects of inflicted damage on ships mission must be analyzed.

In the remaining sections of the paper, we discuss:

1. Why a damage tolerance analysis is necessary;

2. What damage tolerance analysis techniques are currently used, their strengths and weaknesses;

3. How CADSDiS fits into the design process;

4. How the program is actually used, with examples; and

5. What are the status, limitations, and benefits of the CADSDiS model.

* Survivability Review Group Final Report on Frigate Survivability, as reported in a classified document.

DAMAGE TOLERANCE: THE NEED FOR SURVIVABILITY ANALYSES

The design of survivable combatant surface ships has generally followed these principles:

- Where possible redundant, widely separated systems should be provided for all vital functions.

- If a vital function cannot be made redundant, all primary and support equipments for that system should be located together.

- Vital equipment and systems should be inherently hardened against specified weapon effects.

- Selected sections of the ship structure should be armored.

Battle damage reports on World War II combatant ships showed that these ships had high levels of survivability because most combat systems were redundant, widely separated, and manually operated. For example, because most ships were steam powered, emergency diesel generators were provided as backups and were separated from the main steam turbogenerators.

Current ship design is driven by significant changes in the threat spectrum, dramatic advances in technology (e.g. solid state electronics, gas turbines), cost, and reduced manning. As a direct outgrowth of the changes in threat spectrum and technology, ship designs are shifting towards enhanced combat capability based on sophisticated, remotely operated, and highly integrated vital systems. Because cost has increased with the increased combat performance capability, the survivability "requirement" to provide redundant, widely separated vital functions has become a significant tradeoff parameter. For instance, one modern launcher system on a ship can operationally replace older multiple, separated launchers. Use of gas turbine or diesel powered ships service electrical generators has resulted in the elimination of "emergency" generators. Reduced manning dictates increased automation and centralization of functions.

The net effect of these changes on ship survivability is that maintaining combat capability during and following battle-induced damage has become a much more complex issue. Survivability analyses must be conducted at the level of the combat mission (anti-air warfare (AAW), anti-submarine warfare (ASW), etc.), and then they must integrate the applicable combat systems with all the associated vital HM&E support functions. The whole is not necessarily equal to the sum of its parts where total ship survivability is concerned.

To illustrate the problem, ony may consider the AAW mission area. It consists of search radars, fire control radars, launchers, computers, intraship communications, and all associated mechanical systems (chilled water, compressed air, air conditioning, etc.) and electrical power support systems. Continuous effective AAW performance (under damaged conditions) requires that all these systems continue to function. However, because of the complexity and size of a naval ship, the design of each system is delegated to a different specialized design group. Within each design group, survivability design guidelines and practices have evolved over the years, and are invoked, as appropriate, at the functional level. The firemain system, which is generally a loop configuration with many cross-connects and

segregating valves, will have vital electrical power panels supplied by at least a normal and an alternate source of power. So, at the functional area level, its survivability may be adequate, but at the point of integration as a total AAW mission area capability, weak links may develop. The result could be, for example, that a ship design has two redundant, widely separated fire control radars that are both supplied with electrical power by a common power panel. This power panel then becomes the weak link. A survivability analysis at the combat mission area level would have identified this problem.

The U.S. Navy has implemented a program to evaluate the survivability of selected existing classes of ships, and to use this information to develop improved survivability design principles for new designs (NAVSEA Survivability Review Group). The DDG 51 design benefited from this effort. The detailed specifications for this ship class include a new section (072f - "Survivability Requirements for Hull, Mechanical, and Electrical Systems on Surface Combatant Ships") that requires Deactivation Diagram-Damage Tolerance Analyses (DD-DTA) for the AAW and ASW mission areas, and for the firefighting systems [1]. Because no computer-based tools were available that directly addressed all the DD-DTA specification requirements, shipbuilders have implemented them manually, which is very labor intensive.

CURRENT TECHNIQUES FOR DESIGNING SURVIVABILITY INTO SHIPS

A number of techniques exist to analyze the survivability of naval surface ships against a spectrum of threat weapons or self-inflicted damage, such as accidental flooding or fires. The procedures range from totally manual, deterministic analyses to sophisticated, multi-hit statistical analyses utilizing Monte Carlo simulations. Regardless of the technique chosen, the basic steps are the same:

a. Develop a deactivation diagram of the mission to be analyzed. This diagram is a series/parallel block diagram that represents the functional flow interrealtionships between all the system, equipments, and components that are required for the mission to achieve a specified minimally acceptable level of operational capability. Parallel elements are functionally redundant. Loss of a parallel component would not reduce the mission operational capability below its specified level. Series components are nonredundant, and a loss of any component in this category would result in loss of mission capability.

b. Assign ship location indices to each element in the deactivation diagram. The type of survivability analysis being conducted will dictate the accuracy required when specifying element locations. For example, if the analysis assumes that any damage to a shipboard compartment results in total destruction of that compartment, then an element location can simply be its associated compartment number. If, however, selected armoring of a single compartment is being analyzed, then the location coordinates of each element within that compartment may be required.

c. Describe the ship compartmentation and structure. Again, the level of detail required is directly related to the type of analysis. The description can range from simply the detail contained in a set of general arrangement drawings to that of specific structural information, such as bulkhead materials of construction and associated thicknesses.

d. Overlay the deactivation diagram elements with location indices (items a and b above) onto the ship description (item c, above). For manual survivability analyses, this could consist of overlays for the general arrangement drawings, whereas detailed structural interrelationships and large numbers of deactivation diagram elements could require use of a computer database.

e. Conduct damage-tolerance analysis. This segment of survivability analyses most directly affects the type of analysis approach chosen. Two generic approaches can be pursued.

The first approach is to calculate the "survivability" index of a ship against specific threat weapons and, where possible, predict secondary damage spread. This approach involves calculating the damage envelope produced when a specific weapon "hits" the ship being studied, and usually includes at least blast overpressure and fragment penetration (conventional and shaped charge). Because of the statistical variability of the data in the requisite calculations, a Monte Carlo simulation is generally employed. The results of this type analysis are generally presented in the form of graphs where P_k (probability of kill of the mission, system, or equipment) is plotted versus the number of hits of the specific threat weapon being analyzed.

A second approach to damage tolerance analysis is weapon independent. The survivability analysis demonstrates that specified levels of combat operational performance are maintained under assumed levels of damage. The damage envelope could be specified, for example, as the loss of a specific compartment or an entire watertight subdivision, or a volume of damage that is "x" by "y" by "z" feet. This type of analysis is deterministic, and the accuracy of the results are limited by the degree to which all systems, equipments, and components related to combat mission have been accurately identified, incorporated into the deactivation diagrams, and located within the ship geometry. The output of such an analysis is simply a statement that mission performance is or is not acceptable after the specified damage has been imposed.

Because this second approach to damage tolerance analysis is deterministic, and therefore non subjective, it can be incorporated into shipbuilding specifications. In fact, variations of it were used for the Survivability Review Group (SRG) and the DDG 51 Detailed Design Specification (Section 072f). More recently, this approach was made part of the General Specifications of the U.S. Navy (1986-Section 072e) [2]. However, implementation for the SRG and the DDG 51 designs was entirely manual. No computer-based design tools were available. The CADSDiS program is intended to fill that gap.

THE CADSDiS MODEL IN THE DESIGN PROCESS

How does CADSDiS fit into the design process? The role of the survivability advocate was discussed above, and here we will consider how people interact with data, hardware, and the CADSDiS software during the design process. A primary use of CADSDiS is in the detailed design phase. Although it is absolutely necessary to lay out the vital equipment with redundancy and separation in mind (as specified in early design phases), the amount of detail available may not require a computer program for a single system.

THE NEED DURING DETAILED DESIGN

In the detailed design and ship alteration phases, however, the quantity of data for even a single system (electrical for instance) makes it very easy for the designer to lose sight of survivability requirements. As the ship is designed, more and more levels of data are defined. CADSDIS may be applied to any stage of any design phase. It performs a usable DD-DTA before all levels of data have been defined. Absence of levels of data may mean that only one HM&E system (electrical), or parts of an HM&E system (e.g. not all electrical cables), have been defined. A "usable" DD-DTA means that the model runs to completion correctly for the given input, and the analyst can add suitable caveats to qualify the output. For example, when CADSDIS is used with only some of the electrical cables defined, the damage analysis will ignore the part of the ship where cables have not been defined rather than indicating a problem with damage to those parts. As far as the computer model is concerned, the physical link does not exist and therefore cannot be broken. Of course, if nonredundant vital electrical equipment (cables defined or not) is in a damaged area, the model will show the mission capability is lost there. After such a run, the analyst would add the caveat that the DD-DTA was done on the ship as currently configured with cable routes defined in certain zones and not in others.

TYPES OF INPUT DATA

Data input for any computer analysis tool can be a significant effort and CADSDIS is no exception. A two fold approach is used to alleviate this problem. The first approach assumes that computers will be used in the overall design process: the question is how much. Given that a computer is already being used, the user must determine how CADSDIS can utilize data already available in digital form. If no digital data exist, the second approach is to make data input as natural as possible through the use of graphics. The use of graphics for both input and output is described later, in the examples of CADSDIS application.

Before one can further discuss the first approach, use of digital input data for CADSDIS, the concept of the "product model" needs to be introduced. No exact definition has been standardized, but Billingsley and Ryan [3] define it as the "collection of geometric and non-geometric information necessary to fully describe the complete ship. In other words, it is the computer definition of the ship." Geometric information may be thought of as the graphic information associated with Computer Aided Design (CAD) systems. The superior design visualization, manipulation, and communication capabilities of CAD systems compared to engineering drawings now make them the preferred medium for developing a design. Most CAD systems allow nongraphic attributes such as weight, load, or use to be associated with graphic entities. CADSDIS uses a subset of this geometric and nongeometric information as data input. Certainly this concept of a "product model" is not a fully realized commodity, not even in the Navy's latest ships such as the DDG 51. However, parts of the "product model" concept have been realized to some degree of completeness. In particular, CADSDIS can take advantage of transferring geometric data from an incomplete "product model" through the use of the Initial Graphics Exchange Specification (IGES). The key to IGES is creating a neutral format, so that no matter what hardware/software configuration is used to create the data, the IGES file format is the same. Although useful, IGES has several problems. First, someone has to create the data, a time consuming and costly endeavor. Since the original data were probably not created with CADSDIS in mind, it will probably be incomplete.

Finally, standards and conventions need to be agreed upon among the various organizations transferring data to facilitate its use. A more complete discussion of IGES can be found in reference [3], and use of IGES data are described in the examples of CADSDiS application later in this paper.

PORTABILITY AND EASE OF USE

Because CADSDiS is meant to be used at the activity doing the ship design, it must be (1) portable and (2) easy to use. No software program can be truly portable, that is, move from one computer environment to a different one without some changes. However, much effort was made in CADSDiS development to minimize any software conversion effort. The damage tolerance analysis software is not tied to a particular vendor's hardware, peripherals, or CAD software. CADSDiS is written in ANSI STD FORTRAN 77 for use on any general-purpose mainframe or minicomputer.

Graphic input and output are an integral part of the analysis to make the designer's job easier. There is a price to pay for graphics ease of use and it has to do with software portability. To ensure device independence (freedom to use any graphics peripheral), commercial software products such as Megatek's TEMPLATE on the NAVSEA VAX are used. All references to graphics flow through a "narrow funnel" in the FORTRAN code. This "narrow funnel" interfacing with a commercial software product must be changed when converting to a different computer system. A description of the details covering the above and other issues necessary for software conversion at a new installation may be found in reference [4].

The second requirement, ease of use, is, of course, a relative term. But once the input data are assembled--ship geometry and systems are described--exercising the model is straightforward. This is facilited by a consistent user interface with on-line help and a menu structure. A User's Guide, reference [5], provides excellent documentation to lead the novice through the use of the model. The examples of CADSDiS application given later are taken from the User's Guide.

THE MODEL'S SPECIFIC ROLE

Figure 1 is a diagram showing how CADSDiS fits into the design process. The proposed view of the design process may be thought of in several ways. In one view, the loop may represent a whole design phase in the design spiral. On the other hand, the loop could iterate through itself several times in a single design phase, for instance detailed design. Initialization, here, would mean the contract design package that was provided to the shipbuilder. A Navy contract package typically contains definitive and binding definition of hull form and arrangements. It would also have guidance information on structures, equipment arrangements, and distribution system configurations together with specifications which define standards (Gen Specs 072e for example) for the completion of the ship [3]. In Figure 1, note that the ship as defined in ellipse 2 is for survivability analysis only. Ellipse 1 represents the definitive "product model" available to all design disciplines that is "updated" as the normal ship design progresses. This "product model" is changed by survivability requirements only after other design constraints have been satisfied. Secondly, the tight loop between ellipses 2 and 3 shows the power of CADSDiS to impact the design in a timely fashion, as opposed to a strictly manual effort.

To summarize, CADSDiS performs a deactivation diagram-damage tolerance analysis:

- at different activities,
- in different design phases,
- for different mission areas,
- for a ship organized by system or zone,
- for a ship or system partially or entirely defined,
- for any assumed damage criteria.

APPLICATION EXAMPLES

The preceding discussion provided an overview of a DD-DTA, why it is necessary, and how CADSDiS fits into the design process. Specific examples using CADSDiS to perform a DD-DTA are presented here. These examples deal with a hypothetical electrical system supporting a partial combat system on a DDG-like ship. The examples are for an electrical systems because the CADSDiS software currently models only that distribution system. As we go through brief illustrations defining the input data and a slightly more complete one showing the damage analysis and results, all of the figures shown are replicas of images created by the CADSDiS program. The images shown in the paper are black and white only, but a more readable and preferred presentation can be achieved using a color terminal.

The primary CADSDiS user interface is through a hierarachical menu. At each level, the user has a list of available menu items. Each item either performs an action or moves the user to a lower level. Entering HELP and the item name at any point provides a brief explanation.

Figure 2 shows the screen with the top level menu displayed as well as an example of the HELP command. Six of these items are used in the four-step approach to a DD-DTA as follows:

1). Ship Definition. IGES PROCESSOR and SHIP DEFINITION functions define the ship's geometry (decks, compartments, firezones, and watertight bulkheads) with IGES providing the ability to process geometrical data defined elsewhere.

2). System Definition. In SYSTEM DEFINITION the user enters and locates the distribution system within the previously defined ship geometry, i.e., in a particular compartment. The distribution system consists of vital equipment (final users of electrical power such as radars, signal data processors, chill water pumps, etc.), power cables, distribution elements (switchboards, power panels, etc), and sources (generators). While the above is displayed graphically, LIST provides distributed system reports organized by cable, compartment, or component (vital equipment, distribution element, source).

3). Damage. In DAMAGE ANALYSIS the program evaluates the effects of damage on ship mission performance. To do so, the user must first provide a Deactivation Diagram file of the vital equipment defining the functional relationships of individual equipments to ship mission area as an input to CADSDiS. Then the user defines damage parameters, for instance a damage region and one or more locations at which the damage region is to be applied.

4). Assessment. The RESULTS POST PROCESSOR allows the user a choice of displaying the results of the damage analysis, either on the screen or in hard copy, in graphical or tabular format.

In the first example, CADSDiS IGES PROCESSOR can take advantage of data created on a different computer system for other than CADSDiS use. When designing the DDG 51, NAVSEA utilized a Computer Vision CAD system with the ability to create IGES files. Figure 3 shows the compartment boundaries and a deck outline initially created from that file. Skipping through several steps in the input process, figure 4 shows the compartment boundaries in various deck outlines with some components and cables defined. Compartments are numbered from 1 to 74; the dashed lines represent the power cables. As figure 4 indicates, all components and cables are tied only to compartments, not to any particular location in a compartment. The network shown is for a hypothetical incomplete power system supporting a radar.

For the second example, the ship and a very simplified AAW system, consisting of a radar, two missile launchers, and two guns with their supporting power system, will be "damaged." A detailed description of this sample AAW system may be found in an earlier version of CADSDiS documented in reference [6]. After entering DAMAGE ANALYSIS, the user would select DEFINE REGION. There, he has a choice of defining a rectangular or ellipsoid damage region. The SRG report utilized the ellipsoid shape, while the DDG-51 specification calls for a rectangular volume of damage. In this example, the rectangular command was chosen and a volume size defined. Now the user would need to specify where the damage region is to be applied. Figure 5 shows this definition process with the Rectangular-shaped damage region being centered at five locations. Figure 6 shows the REPORT command displaying the current settings of the damage analysis parameters. At the bottom of this figure, five lines starting with "No" indicate what other factors could have been used to specify damage to the ship or system. If any required parameters had not been selected, the program would issue a message after the RUN command prompting the user to return to the specific commands to complete the definition. CADSDiS uses the assumption discussed earlier that if any part of a compartment is within the damage region, then everything in the compartment is considered destroyed. Figure 7 is an isometric presentation showing the affected compartments highlighted for one of the five damage regions.

To continue this example, CADSDiS presents the status of a damage run in either tabular listings or "barplots." In presenting results, CADSDiS makes a distinction in determining why components fail. A component may fail because it was in a compartment directly affected by the damage region. If so, it is considered destroyed or OFF. Or, a component may fail even though it was in a compartment outside the damaged region because no power can be supplied to it. Power may be lost because of damage to other components or cables. This loss of power is indicated by "NPW" or No Power. If a component is not damaged and has power, it is considered ON. For each of the damaged regions, five in this example, the following status reports may be listed:

- damaged compartments, components, or cables,
- components outside the damaged region which have lost power,
- all components with status flags showing ON, OFF, or NPW,
- system status ON or OFF,
- location of damage region and region type.

To present the same information graphically, a "barplot" is used. The plot layout is in a matrix format. Figure 8 shows the barplot of system status versus damage location. The horizontal axis may be thought of as the side of the ship. It shows that damaged compartments between frames 144 and 284 would result in the loss of the AAW mission area. In this example, there are five divisions on the horizontal axis corresponding to the five damage regions applied. To see why the mission area is OFF in two regions, figure 9 can be used as a starting point. It uses the same barplot format, only this time the vertical axis lists all components. Figure 10 is useful for pinpointing what caused AAW to be OFF. Here, only these components and cables directly causing AAW to be OFF are shown.

Although the equipment used in this example may not be very realistic, it does illustrate that the effects of damage on vital electrical systems can be quickly analyzed and related to the ship's mission performance.

CONCLUSION

In concluding this paper on the CADSDIS model, the current status and related developmental efforts will be described, and limitations and benefits of the model discussed. The graphics electric module is operational on Digital Equipment Corporation VAX computers at several Navy and commercial activities. Depending on the number of mission areas, level of detailed analysis required, and the amount of computerization already used in the ship design, input data requirements may be extensive. Partial databases for the electric module have been created for the FFG 7, CG 47, and DDG 51 classes. Under sponsorship of NAVSEA, an effort is underway by DTNSRDC, John J. McMullen Associates, and Rockwell Autonetics Marine System to complete the CADSDIS model for the auxiliary and control systems. These systems will be added, the deactivation diagram input process will be facilitated, and the software portability and ease of graphics use that were demonstrated in the electrical module will be continued. The new effort will add ducting (heating, ventilation, air conditioning); piping (seawater, chill water, fuel oil, electronic dry air); cabling (data multiplex system, hydraulic, control); and fixed firefighting (firemain, aqueous film-forming foam (AFFF), Halon). These additions will enable a DD-DTA to be performed for each system, separately or together, in support of different mission areas.

An overview has been presented on the structure, operation and limitations of the CADSDIS model. Benefits to the Navy of the general damage tolerance analysis approach have been discussed. Examples illustrated some applications of the computer model, and highlighted its flexiblity in determining whether the survivability requirements of separation and redundancy in HM&E equipment to support specified combat mission areas have been achieved in ship design.

The CADSDiS computer model possesses several distinct advantages over manual damage tolerance analysis. Besides lowering the cost, the model enables a more complete damage tolerance analysis to be performed. If applicable digital data are available, its major benefit is its interactive ability to be an integral part of the design cycle, so damage tolerance analysis feedback can occur in hours or days rather than weeks or months.

In performing such an analysis, of course, the survivability analyst must keep in mind that CADSDiS results are limited by the accuracy and completeness of the input data and that, because the model is deterministic and weapon independent, it assesses survivability only in terms of specific, predefined levels of damage imposed by the user. Within these constraints, CADSDiS provides the ability to conduct more extensive analyses in a more timely fashion than was formerly possible. It will help ensure that the survivability principles of separation and redundancy are incorporated into ship design and are realized in the ship as built.

REFERENCES

[1] Specifications for Building Guided Missile Destroyer DDG 51 dated March 15, 1985, Naval Sea Systems Command, Washington, D.C. 20362.

[2] General Specifications for Ships of the United States Navy, 1986 Edition, publication, NAVSEA No. S9AA0-AA-SPN-010/GEN-SPEC.

[3] Billingsley, Daniel W. and J. Christopher Ryan, "A Computer System Architecture for Naval Ship Design, Construction, and Service Life Support," TRANS., Soc. Naval Arch. Mar. Eng., Vol. 94 (1986).

[4] "CADSDiS (Electrical) Programmers Manual," Rockwell, Naval Sea Systems Command. Document Number 072-56D5-TN-007 (Feb 1987).

[5] "CADSDiS (Electrical) User's Guide," Rockwell, Naval Sea Systems Command. Document Number 072-56D5-TN-008 (Feb 1987).

[6] Brengs, R., M. Henderson, and R. Milam, "CADSDiS User Manual and Program Documentation," DTNSRDC CMLD-84-18 (Sep 1984).

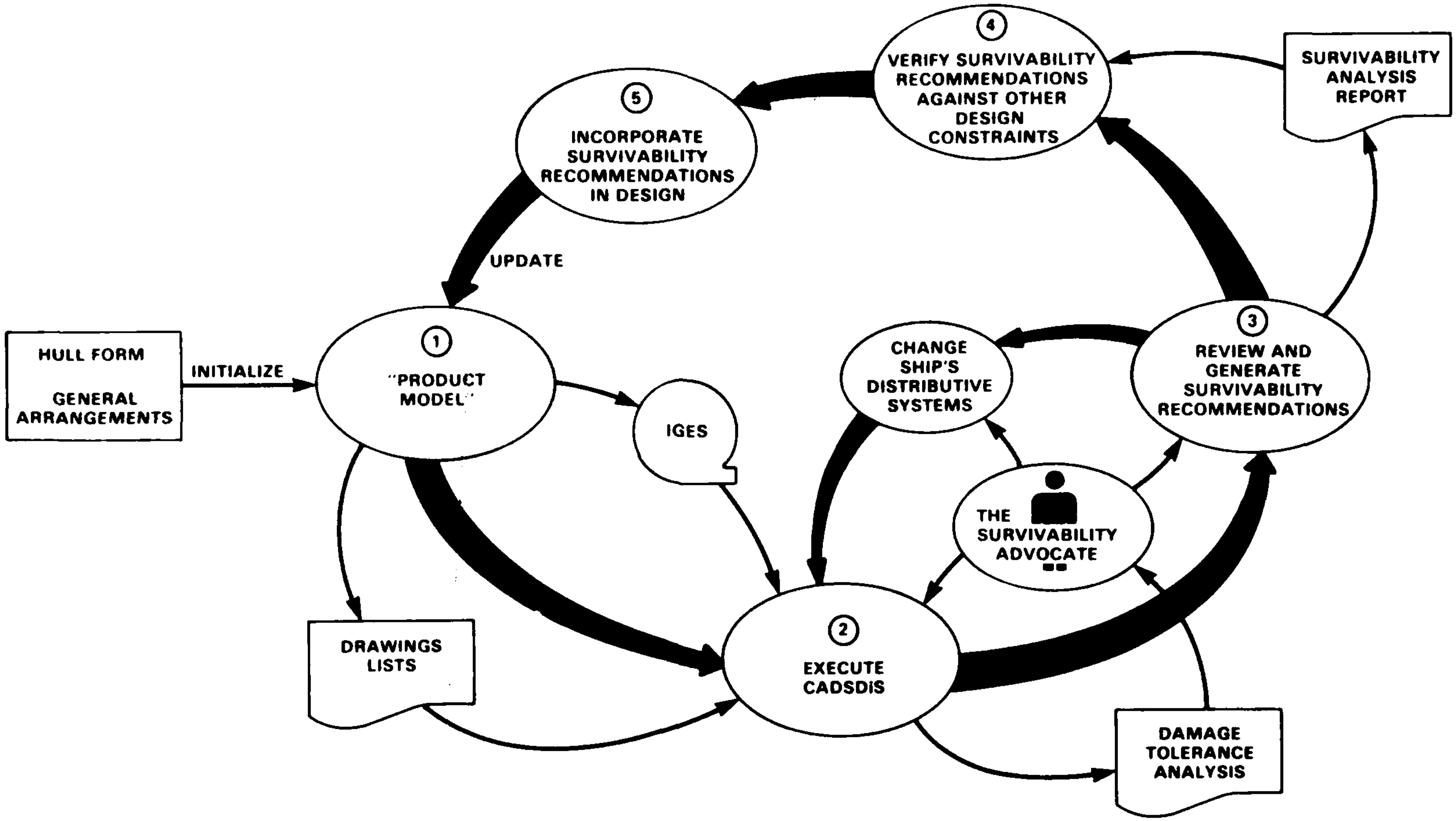

Figure 1. The CADSDiS design process.

```
B>CADSDIS
CX> HELP
     SHIP DEFINITION
     SYSTEM DEFINITION
     LIST UTILITY
     IGES PROCESSOR
     DAMAGE ANALYSIS
     RESULTS POST PROCESSOR
     OPTIONS
     EXIT
CX> HELP IGES
The IGES PROCESSOR module allows the user to display IGES
geometrical data on the screen and use it to define the ship geometry
in the Ship Definition module.
CX>
```

Figure 2. CADSDiS top level menu.

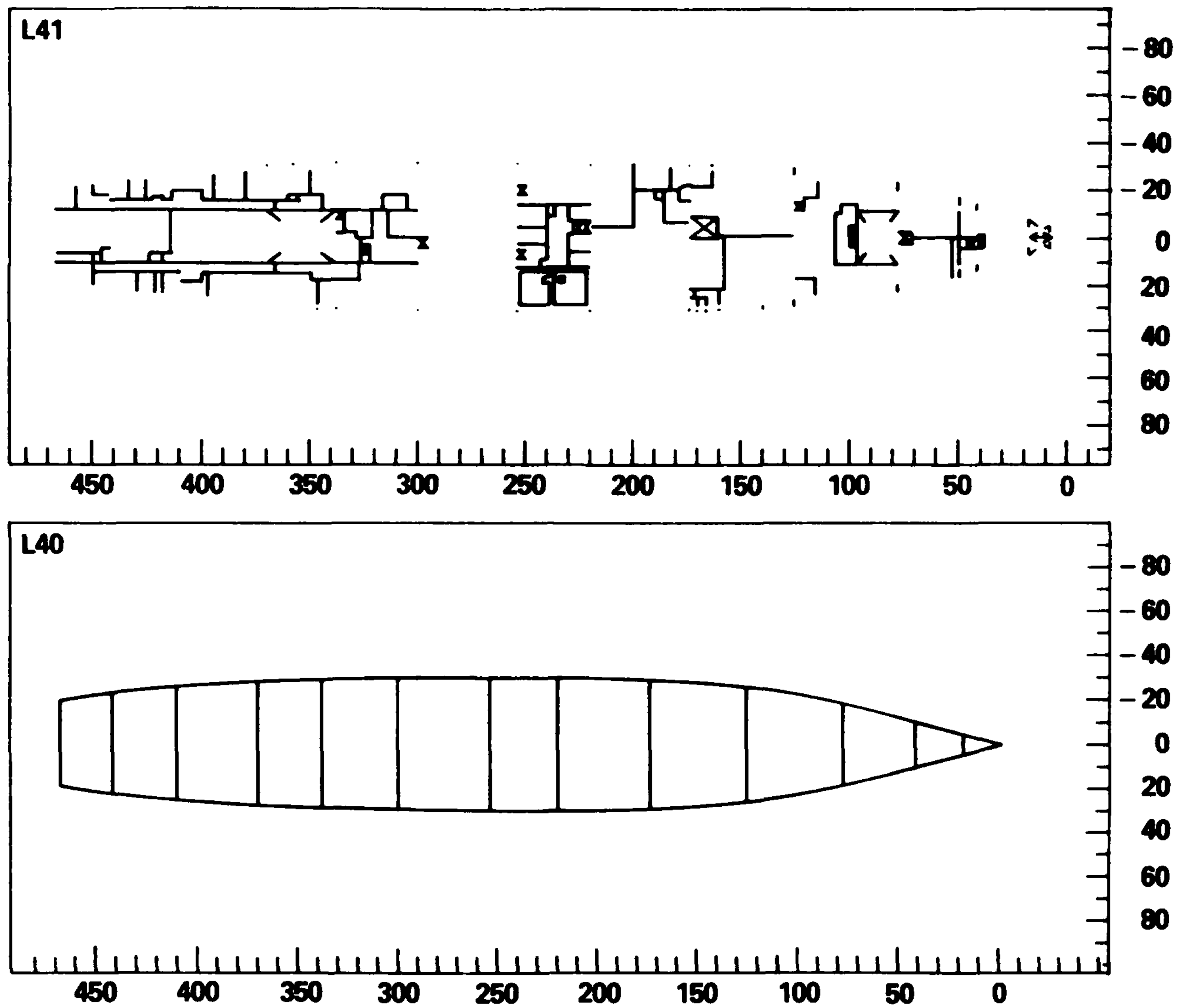

Figure 3. Compartment boundaries and deck outline created from IGES file and used as CADSDiS input.

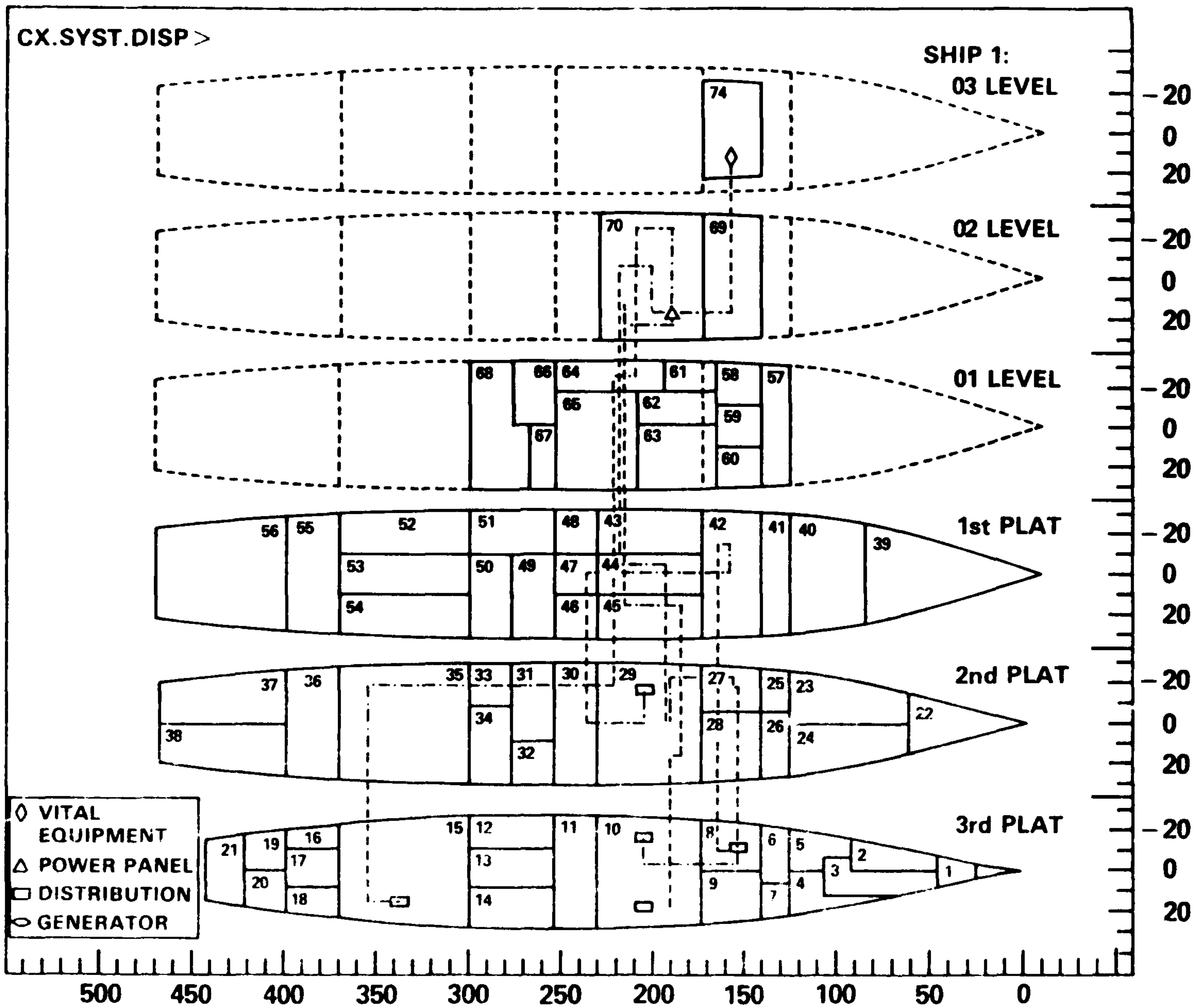

Figure 4. The DISPLAY NETWORK command showing a hypothetical incomplete power system supporting a radar.

```
CX> DAM
CX.DAMA> DEFI
CX.DAMA.DEFI> REC
Rectangular volume selected.
Current x,y,z:      0.00      0.00      0.00
Enter new x,y,z: 60 30 50
New x,y,z:         60.00     30.00     50.00
CX.DAMA.DEFI> LOC
No location(s) specified.
Enter X,Y,Z or 'RESET' to clear: 126 16 25
Enter X,Y,Z or 'RESET' to clear: 174 16 25
Enter X,Y,Z or 'RESET' to clear: 254 18 26
Enter X,Y,Z or 'RESET' to clear: 300 16 25
Enter X,Y,Z or 'RESET' to clear: 370 16 25
Enter X,Y,Z or 'RESET' to clear:
CX.DAMA.DEFI>
```

Figure 5. Damage region definition.

```
CX> DAMA
CX.DAMA> REP
Damage Analysis parameter settings:
system file(s) selected:
   1) $1$DUA1:[NSRDC56D5.ROCKWELL56D5.DEMO]AAW.SYS;1
   asso: 1) $1$DUA1:[NSRDC56D5.ROCKWELL56D5.DEMO]AAW.DEA;1

Rectangular Volume damage region selected.
Current x,y,z:     60.00     30.00     50.00
Number of locations:         5
     X         Y        Z
  126.00     16.00    25.00
  174.00     16.00    25.00
  254.00     16.00    25.00
  300.00     16.00    25.00
  370.00     16.00    25.00
No cables selected.
No components selected.
No compartments selected.
No watertight areas selected.
No firezones selected.
CX.DAMA>
```

Figure 6. Damage parameter report.

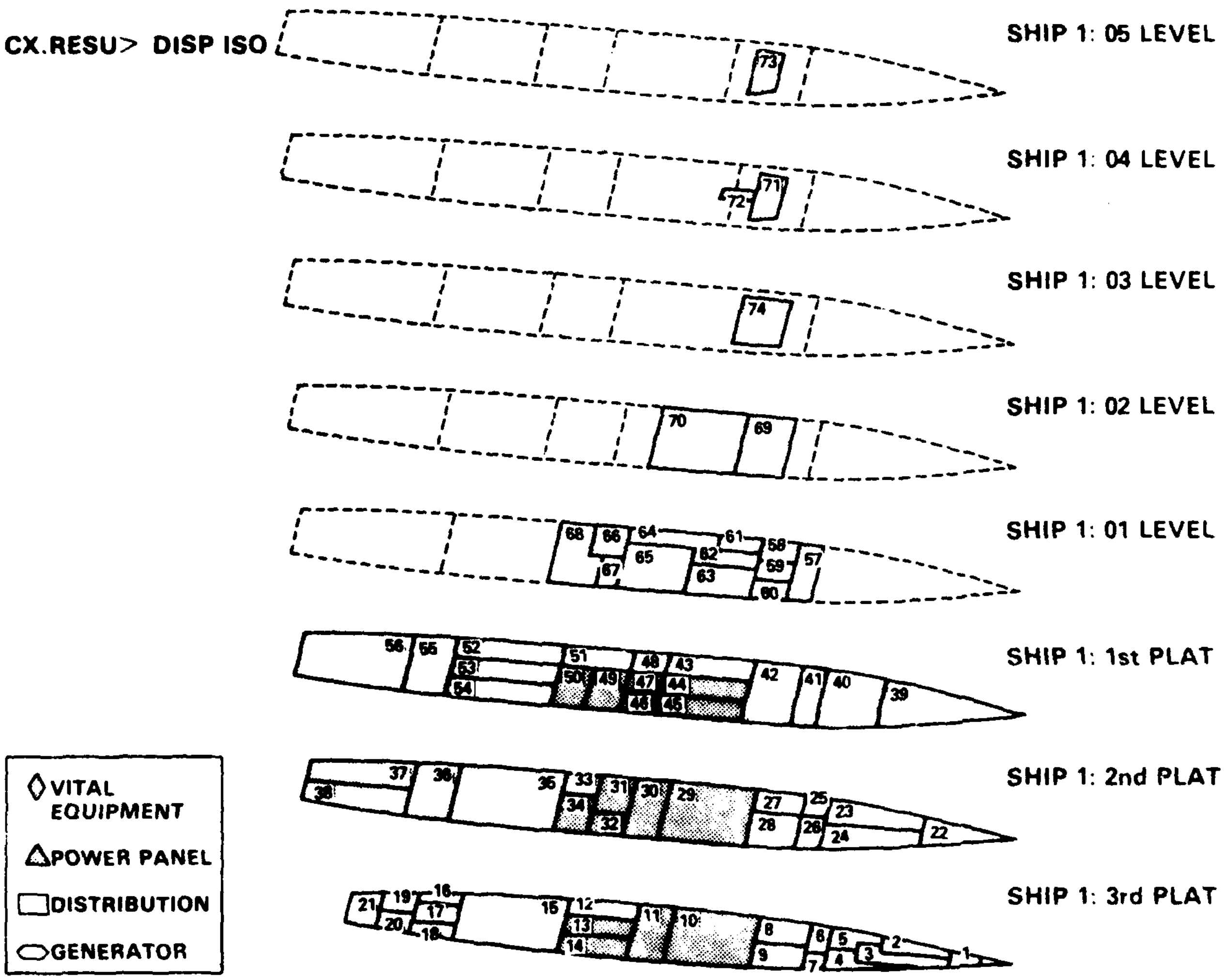

Figure 7. Damage compartments highlighted.

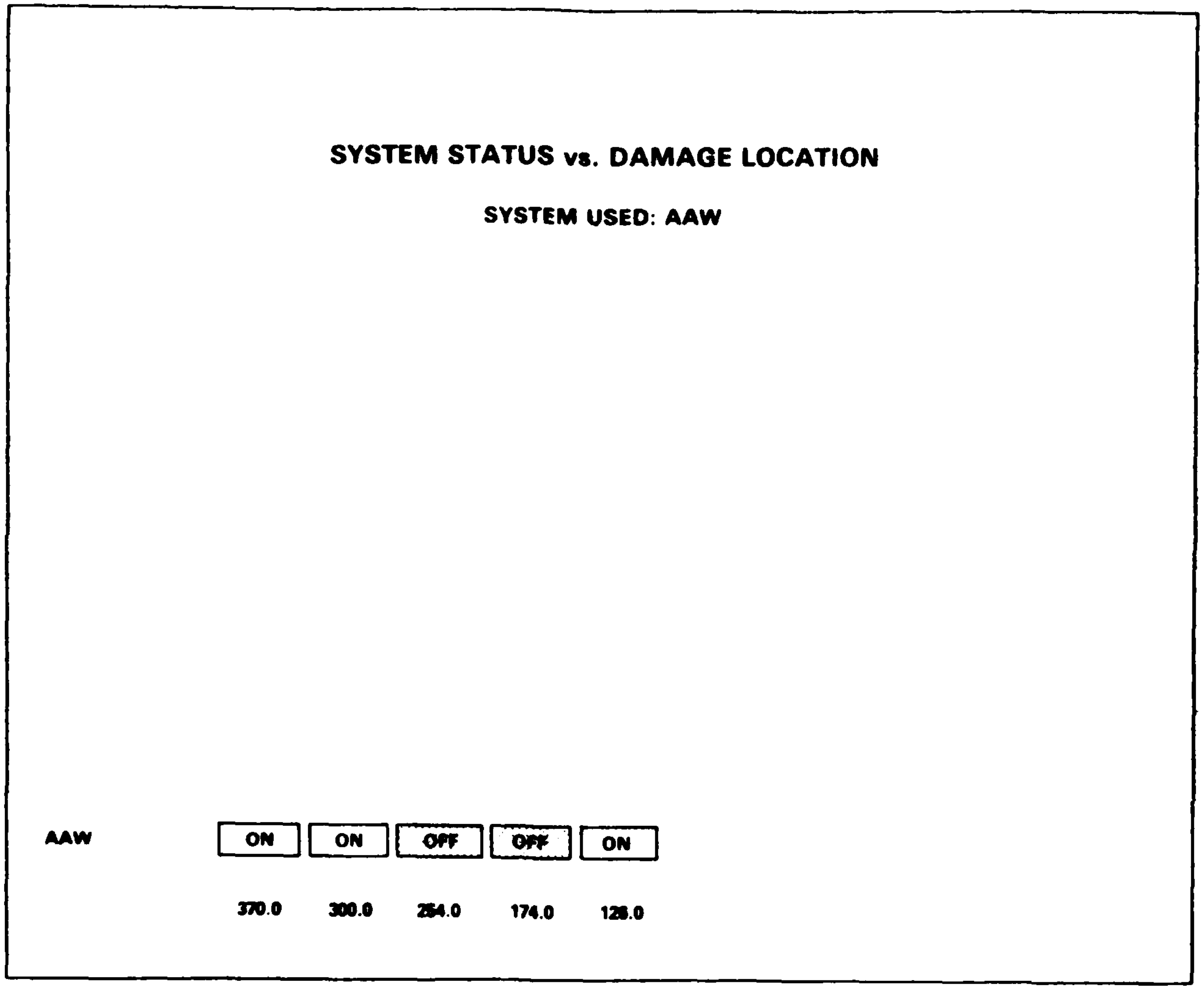

Figure 8. System status barplot.

NEXT PLOT (Y/N)? (Y)

COMPONENT STATUS vs. DAMAGE LOCATION

SYSTEM USED: AAW

PWRPNL02 35 1	ON	ON	NPW	NPW	ON
GUN#2	OFF	ON	ON	ON	ON
PWRPNL2-94-2	OFF	ON	ON	ON	ON
PWRPNL2-80 3	OFF	OFF	ON	ON	ON
MSLLNCHR#2	OFF	OFF	ON	ON	ON
SWBD2SB	OFF	OFF	ON	ON	ON
SWBD1SB	OFF	OFF	ON	ON	ON
SWBD4SB	ON	ON	OFF	OFF	ON
SWBD3SB	ON	ON	OFF	OFF	ON
SWBD2EA	ON	ON	OFF	OFF	ON
PWRPNL1 21 1	ON	ON	NPW	NPW	OFF
LC32	ON	ON	NPW	NPW	ON
MSLLNCHR#1	ON	ON	NPW	NPW	OFF
GUN#1	ON	ON	NPW	NPW	ON
PWRPNL2 10 4	ON	ON	NPW	NPW	ON
	370 0	300 0	254.0	174.0	126.0

Figure 9. Component status barplot.

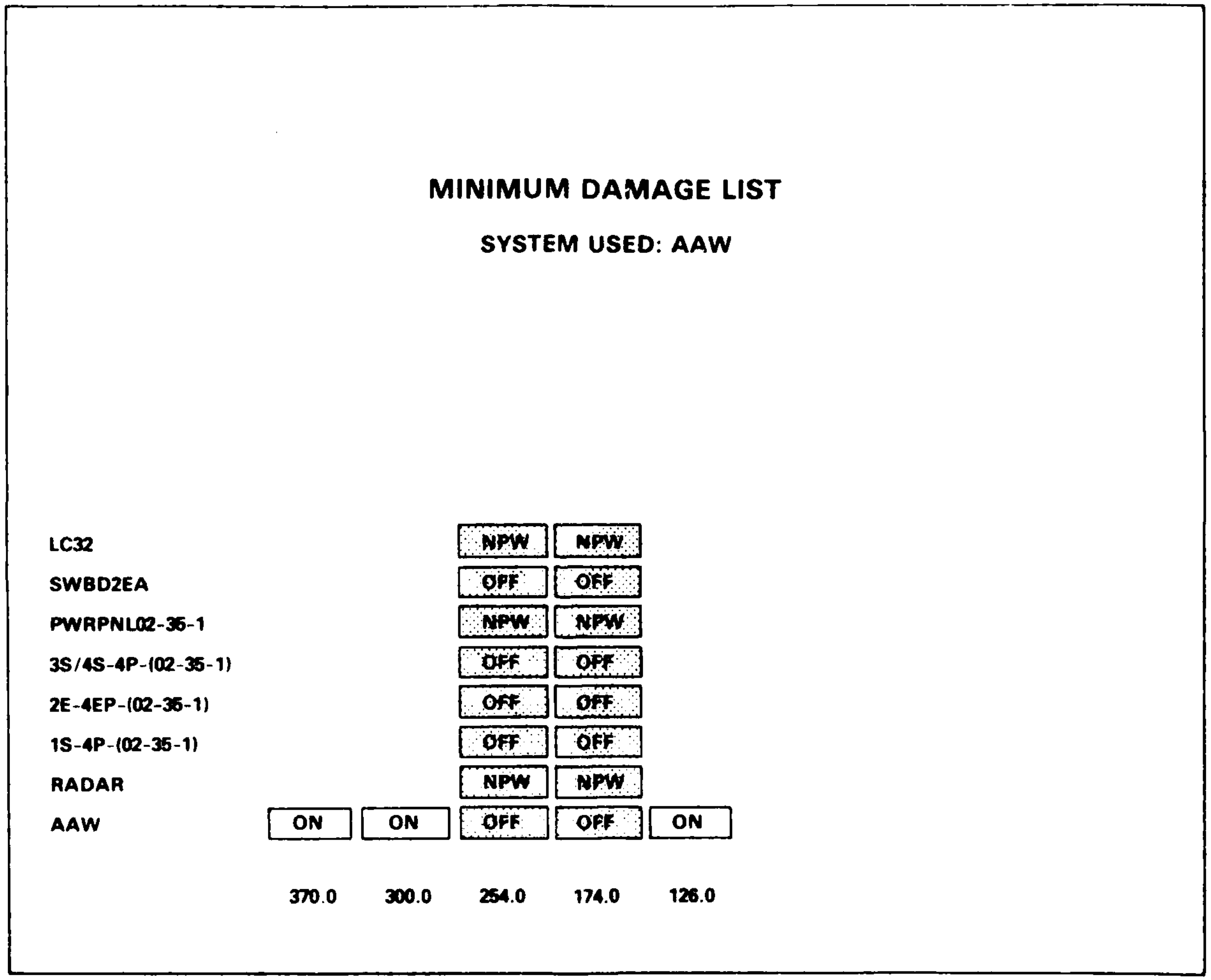

Figure 10. Minimum damage barplot.

END
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DTIC